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RESEARCH MEMORANDUM

EFFECT OF SCREENS IN REDUCING DISTORTION AND DIFFUSION LENGTH FOR A "DUMP" DIFFUSER AT A MACH NUMBER OF 3.85

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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EFFECT OF SCREENS IN REDUCING DISTORTION AND DIFFUSION LENGTH FOR A "DUMP" DIFFUSER AT A MACH NUMBER OF 3.85*

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SUMMARY

An investigation of the effect of screens in a dump-type diffuser was conducted in the Lewis 2- by 2-foot supersonic wind tunnel at a free-stream Mach number of 3.85. The results of this test indicated that a slanted half screen of 0.41 solidity, positioned 0.263 inlet diameter from the cowl lip, would permit shortening the subsonic diffuser from approximately 1.25 to 0.41 inlet diameter with about a 2-percent loss in pressure recovery. The resulting distortion at low diffuser-exit Mach numbers was approximately 8 percent. Results of an analysis of this inlet screen configuration, evaluated on a range basis, are presented.

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INTRODUCTION

As flight altitude increases, keeping airframe structural weight to a minimum becomes increasingly important. For engine nacelles, the subsonic portion of the diffuser is one component for which weight reductions are possible. For example, reference 1 shows that an inlet employing an abrupt area change, or "dump," at the entrance to the subsonic diffuser could be competitive with other current designs with respect to pressure recovery and drag. However, reducing the subsonic-diffuser length to less than 1.25 inlet diameters resulted in excessive flow distortion.

References 2 and 3 indicate that screens or grids can be used to reduce distortion in a duct. Therefore, an investigation was undertaken in the Lewis 2- by 2-foot supersonic wind tunnel to evaluate the effectiveness of various screen configurations in reducing distortion and thus making further shortening of the diffuser possible.

The model used in this investigation is the same as that discussed in reference 1; performance characteristics in terms of flow distortion, mass flow, pressure recovery, and loss in pressure recovery are presented with and without screens at a free-stream Mach number of 3.85 and zero angle of attack. Also presented are the results of an analysis, made by

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the method of reference 4, of the weight reduction required to compensate for the screen pressure loss obtained with the best screen configuration.

SYMBOLS

The following symbols are used in this report:

D	diameter of cowl lip (4.75 in.)
L	longitudinal distance from cowl lip 4796
M	Mach number
m/m_0	exit mass-flow ratio
P	total pressure
$\frac{P_{max} - P_{min}}{P_{av}}$	flow-distortion parameter
ΔP	total-pressure loss across screen measured at station 7(4.0 inlet diam)
r/R	ratio of radius to individual total tubes in rake to inside cowl radius

Subscripts:

av	numerical average
max	maximum
min	minimum
x	individual tubes of rakes 1 and 2
0	free-stream conditions

APPARATUS AND PROCEDURE

The experimental investigation was conducted in the Lewis 2- by 2-foot supersonic wind tunnel at a free-stream Mach number of 3.85 and zero angle of attack. The model is essentially the same as that reported in reference 1. The inlet configuration and details are shown in figure 1, which includes a table listing the various model stations with the corresponding locations in inlet diameters from the cowl lip. (In this report, screen and rake locations also are designated in terms of inlet diameters.) A flush-slot bleed gap set at 0.140 inch was employed at the throat. The bleed air was vented to the free stream through the hollow sting and support struts. In order to prevent laminar separation on the spike, tip roughness was used to cause a turbulent boundary layer.

Since only zero-angle-of-attack data were taken, axisymmetric flow was assumed in the diffuser. Therefore, in order to measure distortion, two additional total-pressure rakes were used. These rakes were positioned at 0.316 and 0.684 inlet diameter, 180° apart but not in line with the existing strut and mass-flow rakes. The survey rake at 0.316 inlet diameter could be moved to either 0.410 or 0.484 inlet diameter when slanted screens were used and was always positioned 0.25 inch downstream of the screens. The survey rake at 0.684 inlet diameter was fixed throughout the investigation.

In this investigation, three screen solidities were used: (1) 0.22 solidity of mesh 6 and 0.02-inch wire, (2) 0.29 solidity of mesh 8 and 0.02-inch wire, and (3) 0.41 solidity of mesh 10 and 0.023-inch wire. The solidity is defined as the area ratio of the projected solid parts or elements of the screen or grid to the total area. A photograph of the three solidities of screens mounted at 0.263 inlet diameter perpendicular to the flow direction is presented in figure 2. Also investigated were a full and a half screen of 0.41 solidity, slanted 30° to the flow direction. The locations of these screens relative to the spike and cowl lip are shown in figure 3. The slanted half screen (fig. 3(b)) occupied 60.2 percent of the projected cross-sectional annular area. Both screens were positioned at 0.263 inlet diameter on the inner periphery of the cowl, as shown in figure 1.

The mass flow through the diffuser was varied by remotely controlling the exit plug (fig. 1). The exit mass flow was calculated by use of the continuity equation, measured static pressure at 4.00 inlet diameters, and calibrated sonic discharge. Pressure recovery was based on an average of 24 total-pressure tubes located 4.00 inlet diameters from the cowl lip (fig. 1). Flow distortion was measured by the total-pressure rakes along the duct and is presented as $(P_{max} - P_{min})/P_{av}$ for each rake station. The total-pressure loss due to screens was measured at the exit rake, 4.00 inlet diameters, for all screen configurations. This rake was used because of its complete over-all total-pressure survey and low distortion for all exit Mach numbers.

RESULTS AND DISCUSSION

Inlet performance without screens (fig. 4) resulted in a peak pressure recovery of 42 percent at a mass-flow ratio of 0.76. The distortion curves indicate excessive distortion at 0.316 and 0.684 inlet diameter and comparatively little distortion at 1.525 and 4.00 inlet diameters. As a result, the diffuser length for reasonable distortion levels should be between 0.684 and 1.525 inlet diameters. In reference 1, this length was determined as approximately 1.25 inlet diameters. Since the distortions at 1.525 and 4.00 inlet diameters are rather low with no screens present, the remaining figures of this report present distortion data only from surveys at 0.316, 0.410, 0.484, and 0.684 inlet diameter.

The effect of screen solidity on distortion for screens perpendicular to the flow direction is shown in figure 5(a). For this series of screens, pressure surveys were taken at 0.316 and 0.684 inlet diameter. Comparison of the distortion levels for the three screens tested indicates that the 0.41-solidity screen exhibited the best reduction in distortion at both 0.316 and 0.684 inlet diameter. However, the total-pressure loss of the 0.41 screen was the highest of the three screens. 4796

The total-pressure profiles for the three screen configurations are compared with the no-screen configuration in figures 5(b) and (c). With no screen in the diffuser, the high-velocity air is located around the outer periphery at both 0.316 and 0.684 inlet diameter. At 0.316 inlet diameter, this high-velocity air is gradually reduced and shifts toward the centerbody with increasing screen solidity. However, flow separation still persists at the centerbody. At 0.684 inlet diameter, the pressure profile of the 0.41-solidity screen indicates that the high-velocity air shifts gradually to the centerbody as diffuser-exit Mach number is decreased. For the other screens, this shift does not occur until the diffuser-exit Mach number goes below 0.160. In general, the 0.41-solidity screen had much better profiles and lower level of distortion than the other perpendicular screens.

Since the 0.41-solidity screen exhibited the best distortion reduction, an effort was made to reduce the pressure loss associated with this screen. To accomplish this, the 0.41-solidity screen was slanted 30° to the flow direction, a method employed in references 2 and 3. The results obtained from slanting the screen are presented in figure 6. The data of figure 6(a) indicate that the pressure loss was reduced slightly at the higher exit Mach numbers. In comparing the distortion levels (fig. 6(a)) of the two screens, slanted and perpendicular, the slanted screen was more effective in reducing distortion at 0.684 inlet diameter. However, only a relative comparison can be made on the lower distortion figure because of the different survey stations (0.484 and 0.316 inlet diam) used with the slanted and the perpendicular screens. The total-pressure profiles of figures 6(b) and (c) show the effectiveness of the slanted screen on the high-velocity air located on the outer periphery of the cowl. With the slanted screen, little or no separation is encountered at the centerbody for the 0.484-inlet-diameter station. A slight separation off the outer periphery for 0.684 inlet diameter is indicated for the lower exit Mach numbers. The profiles at 0.684 inlet diameter are about the same for the slanted screen as for the perpendicular screen.

In a further effort to reduce the total-pressure loss for this screen, a slanted half screen of the same solidity was employed with the idea that, since the high-velocity-air region is located on the outer periphery, the portion of screen close to the centerbody may not be needed. This screen occupied 60.2 percent of the projected cross-sectional annular area of the duct. The results are presented in figure 7. Again, only a relative com-
4796 parison of distortion (fig. 7(a)) can be made between the slanted full and half screens because of the different survey stations (0.484 and 0.410, respectively). However, data indicate that the slanted half screen is nearly as effective in reducing distortion as the slanted full screen, with a lower loss in pressure recovery. At the low diffuser-exit Mach numbers, the distortion for the slanted half screen is about 8 percent at a station 0.41 inlet diameter from the cowl lip. The pressure profiles of figures 7(b) and (c) indicate that the slanted half screen is about as effective in leveling out profiles as the full slanted screen.

Reference 1 shows that the diffusion length required with no screens was approximately 1.25 inlet diameters. Employing the slanted half screen of 0.41 solidity reduces this diffusion length to approximately 0.41 inlet diameter. In order to evaluate any gains realized by the use of screens, an analysis was made of the weight savings required (by shortening the diffuser) to compensate for the loss in pressure recovery due to the screen. These calculations, using the method and assumptions listed in reference 4, were made for a ramjet-interceptor-type and a bombardment-type missile at a free-stream Mach number of 3.85.

To evaluate the over-all effectiveness of the best screen configuration, the performance of the screen and the no-screen configurations should be compared at the same inlet mass-flow ratio in order to have the same external drag. Figure 8 presents the inlet pressure recoveries of the 0.41-solidity slanted half-screen and the no-screen configurations as a function of mass-flow ratio. When the two pressure recoveries are compared at the same mass-flow ratio (fig. 8), the loss in pressure recovery caused by the screen is greater than when compared at the same diffuser-exit Mach number, as in figure 7(a). The difference in pressure recovery at the same mass-flow ratio is about 2 percent, which represents the loss across the screen since the inlet conditions are the same.

For this analysis, the inlet operating point for maximum range was determined by the method of reference 4 with the aid of figure 8; this point was located at a mass-flow ratio of 0.800. At this condition, with a loss in pressure recovery of 0.018 caused by the screen, a reduction of 2.5 percent of engine weight is required for an interceptor ramjet missile for the same range as without the screen. For the bombardment ramjet missile at the same inlet conditions, a reduction of about 8.5 percent of the engine weight is required.

It has been demonstrated that the use of screens can result in shortening the diffuser by 0.84 inlet diameter. For a typical ramjet engine having an over-all length-diameter ratio of 6, this represents 14 percent of the engine length. Thus, reducing the engine weight by at least the calculated percentages of 2.5 and 8.5 percent would appear to be feasible.

SUMMARY OF RESULTS

In an investigation of screens in a dump-type diffuser at a free-stream Mach number of 3.85, the following results were obtained: 4796

1. The subsonic diffuser can be shortened to approximately 0.41 inlet diameter by locating a screen as close as 0.263 inlet diameter to the cowl lip.

2. The 0.41-solidity slanted half screen located around the outer periphery was more effective than the full screens.

3. The best screen configuration gave distortions of about 8 percent for the low diffuser-exit Mach numbers at approximately 0.41 inlet diameter, with only about 2-percent loss in pressure recovery.

4. Use of screens in reducing diffuser length was shown to be feasible if over-all engine weight can be reduced by approximately 2.5 percent for the interceptor missile and 8.5 percent for the bombardment missile.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, March 21, 1958

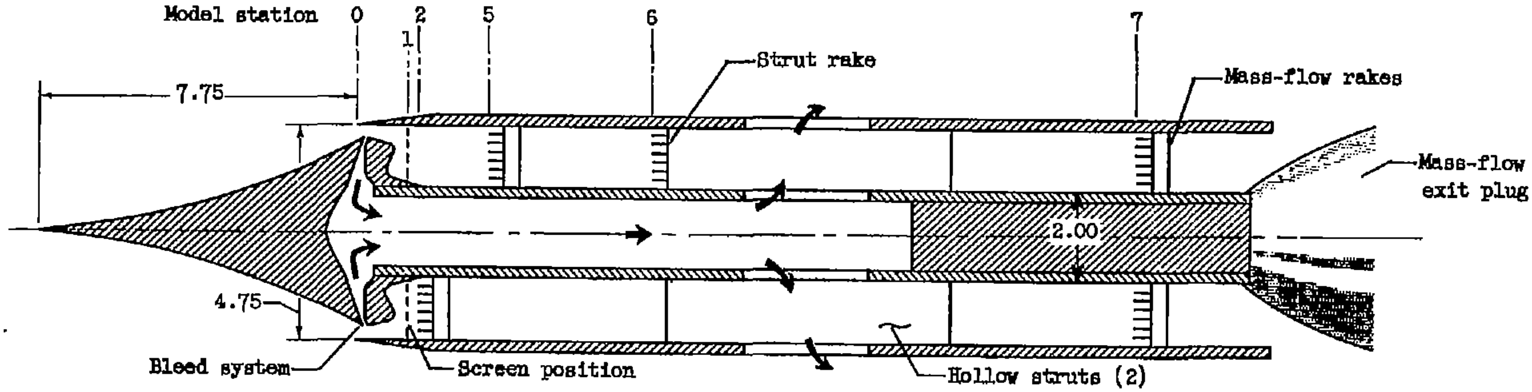
REFERENCES

1. Connors, James F., and Flaherty, Richard J.: High Mach Number, Low-Cowl-Drag, External-Compression Inlet with Subsonic Dump Diffuser. NACA RM E58A09, 1958.

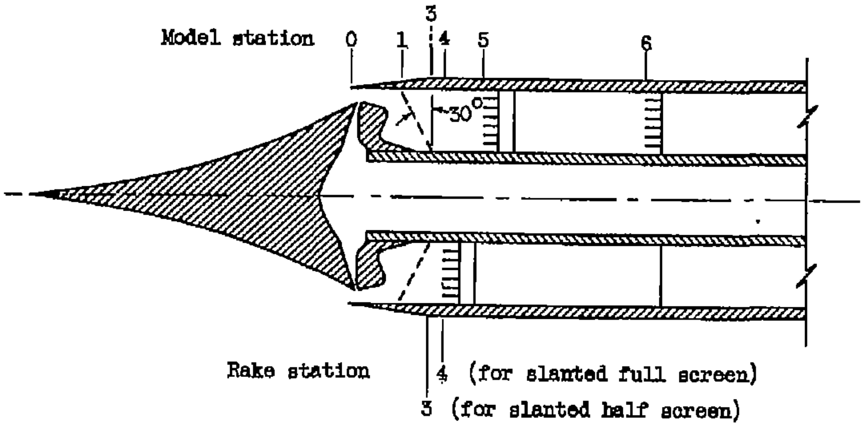
2. Hoerner, S. F.: Pressure Losses Across Screens and Grids. AF Tech. Rep. 6289, WADC, Nov. 1950.

3. Wood, Charles C., and Knip, Gerald, Jr.: An Investigation of Screens for Removing Distortions in Ducted Flows at High Subsonic Speeds. NACA RM L57G08, 1957.

4. Weber, Richard J., and Luidens, Roger W.: A Simplified Method for Evaluating Jet-Propulsion-System Components in Terms of Airplane Performance. NACA RM E56J26, 1956.



(a) Inlet with screens perpendicular to flow.



Model station	Length from cowl lip, L, in.	Length-diameter ratio, L/D, inlet diam
1	1.25	0.263
2	1.50	.316
3	1.95	.410
4	2.30	.484
5	3.25	.684
6	7.25	1.525
7	19.00	4.00

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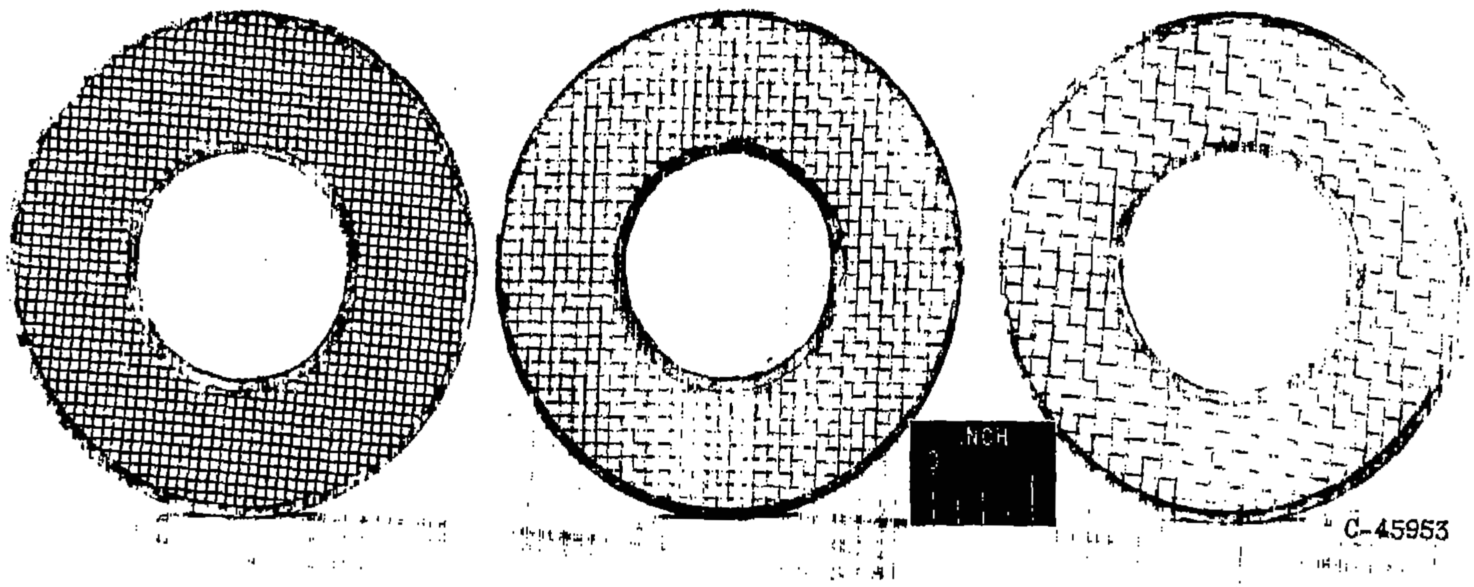
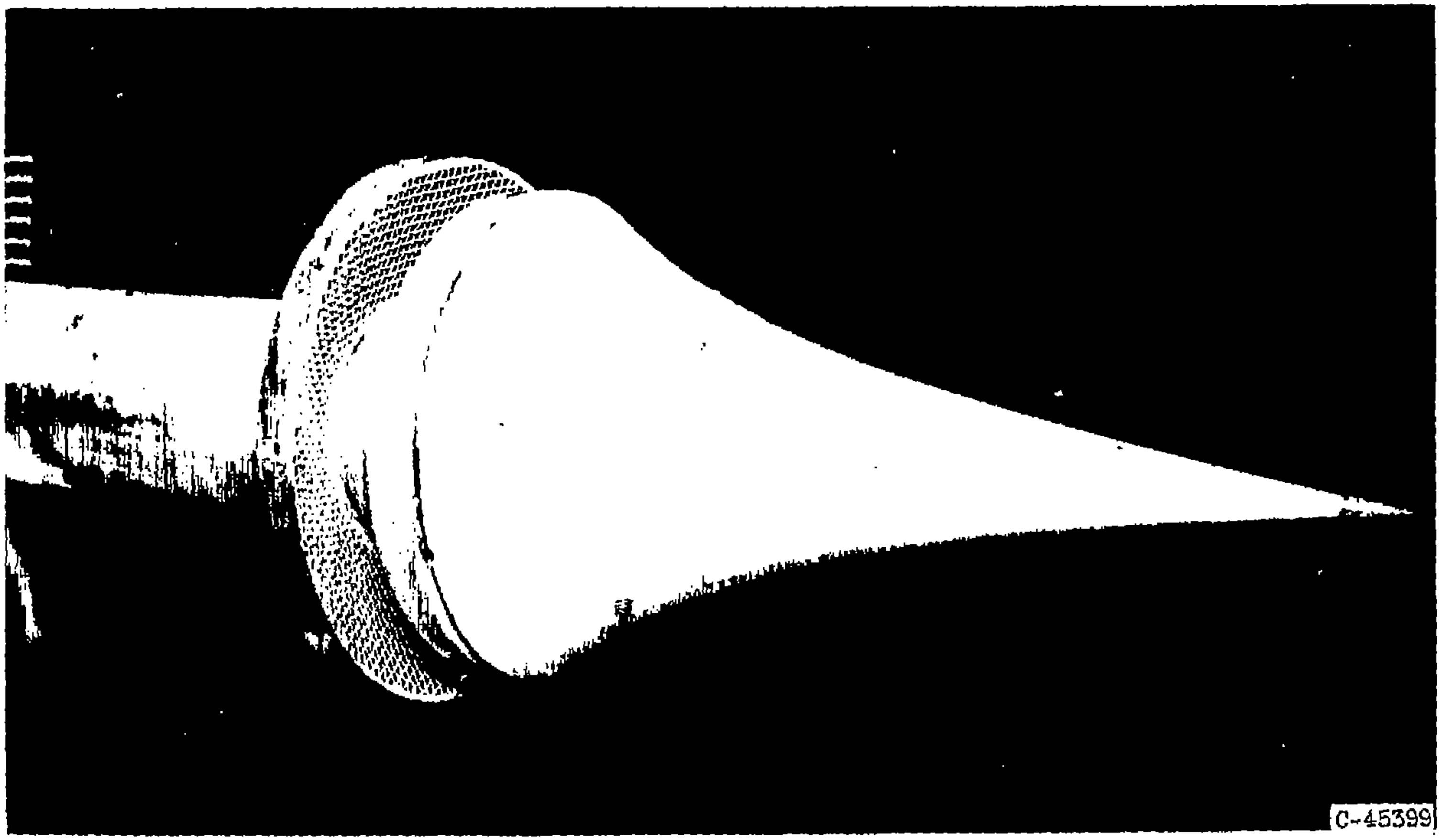
(b) Inlet with screens slanted 30° to flow.

Figure 1. - Model details. (All dimensions in inches.)



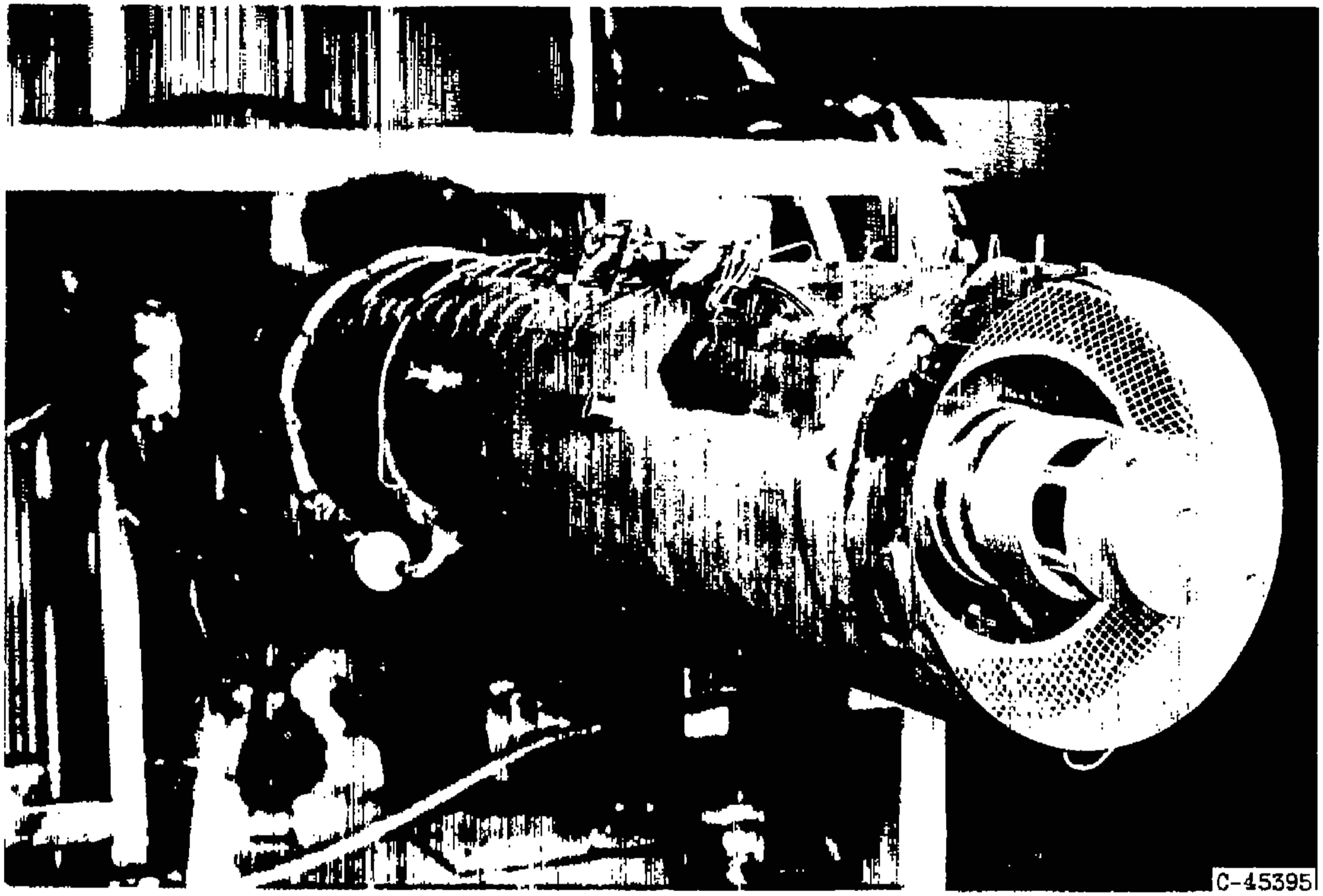
(a) Solidity, 0.41. (b) Solidity, 0.29. (c) Solidity, 0.22.

Figure 2. - Perpendicular screens showing three solidities.



(a) Full screen.

Figure 3. - Screen of 0.41 solidity slanted 30° to flow direction.



(b) Half screen.

Figure 3. - Concluded. Screen of 0.41 solidity slanted 30° to flow direction.

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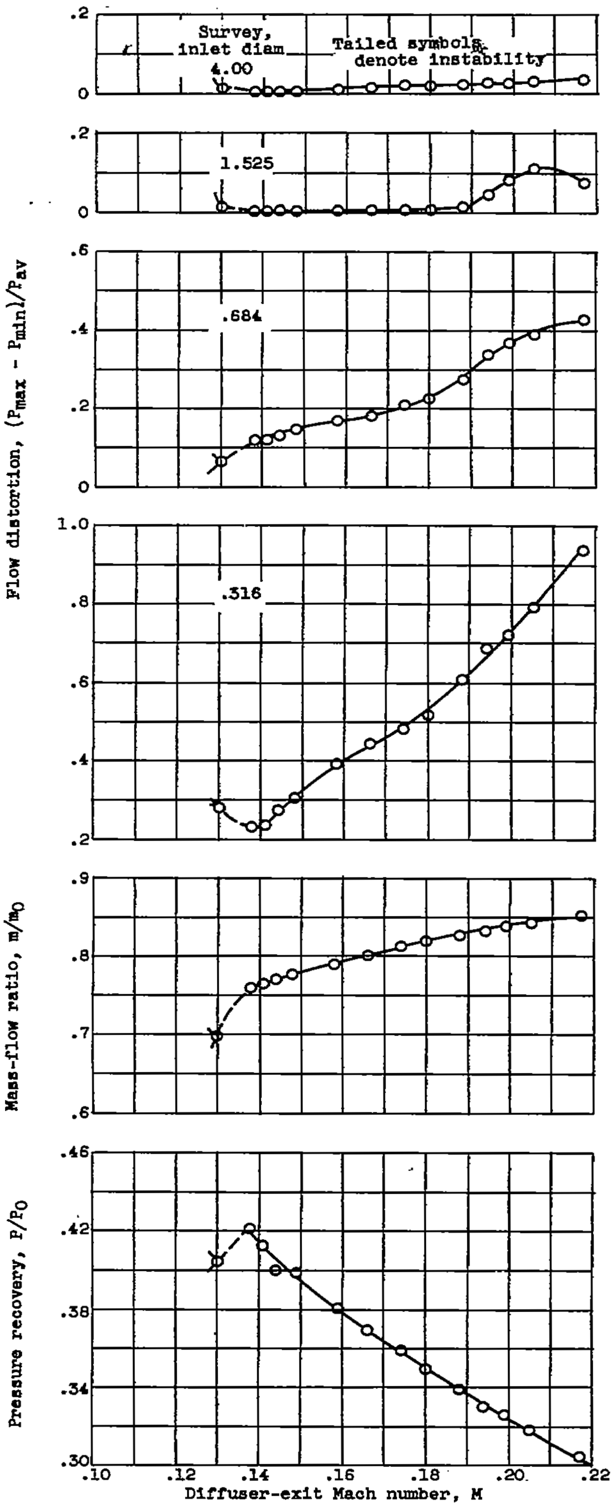
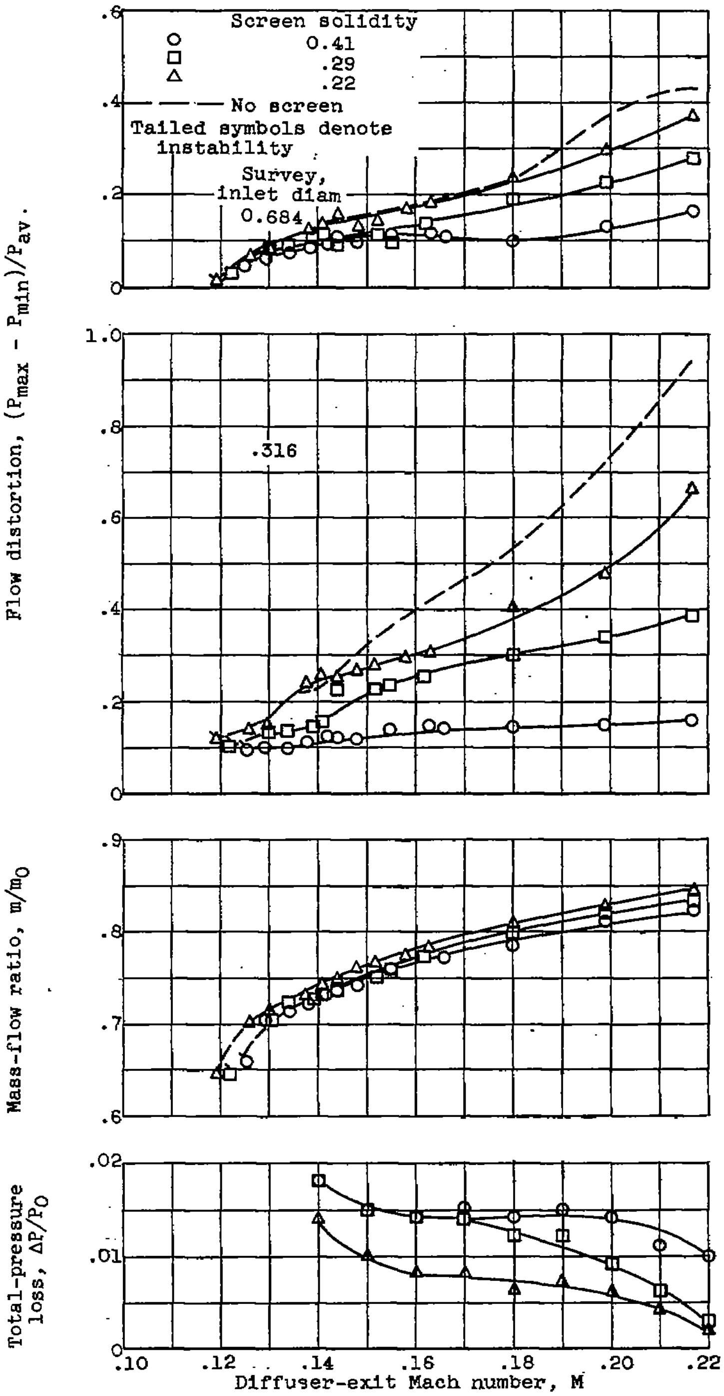


Figure 4. - Diffuser performance without screens.



(a) Flow distortion, mass-flow ratio, and total-pressure loss.

Figure 5. - Effect of screen solidity of full screens perpendicular to flow direction.

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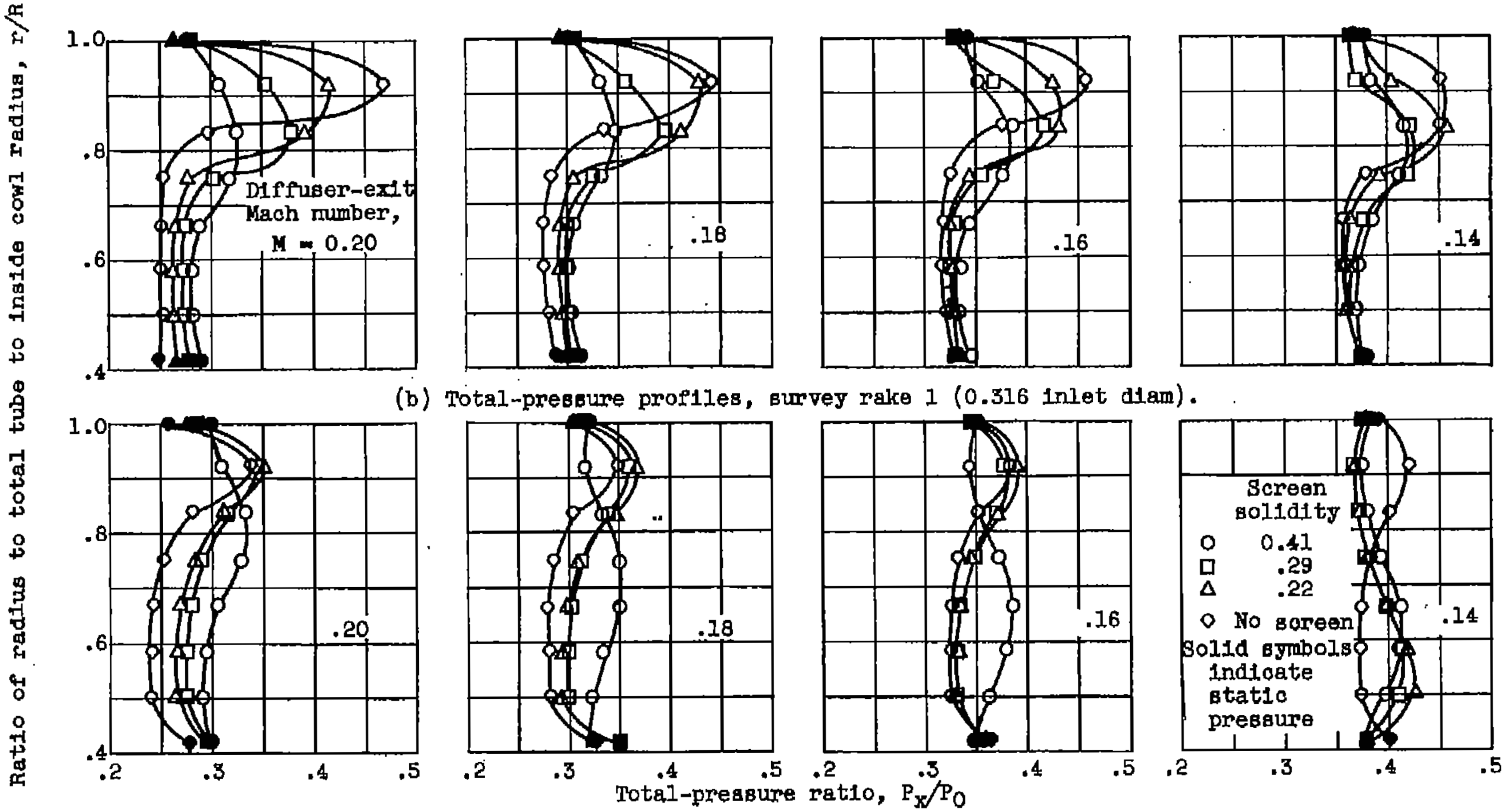

(b) Total-pressure profiles, survey rake 1 (0.316 inlet diam).

(c) Total-pressure profiles, survey rake 2 (0.684 inlet diam).

Figure 5. - Concluded. Effect of screen solidity of full screens perpendicular to flow direction.

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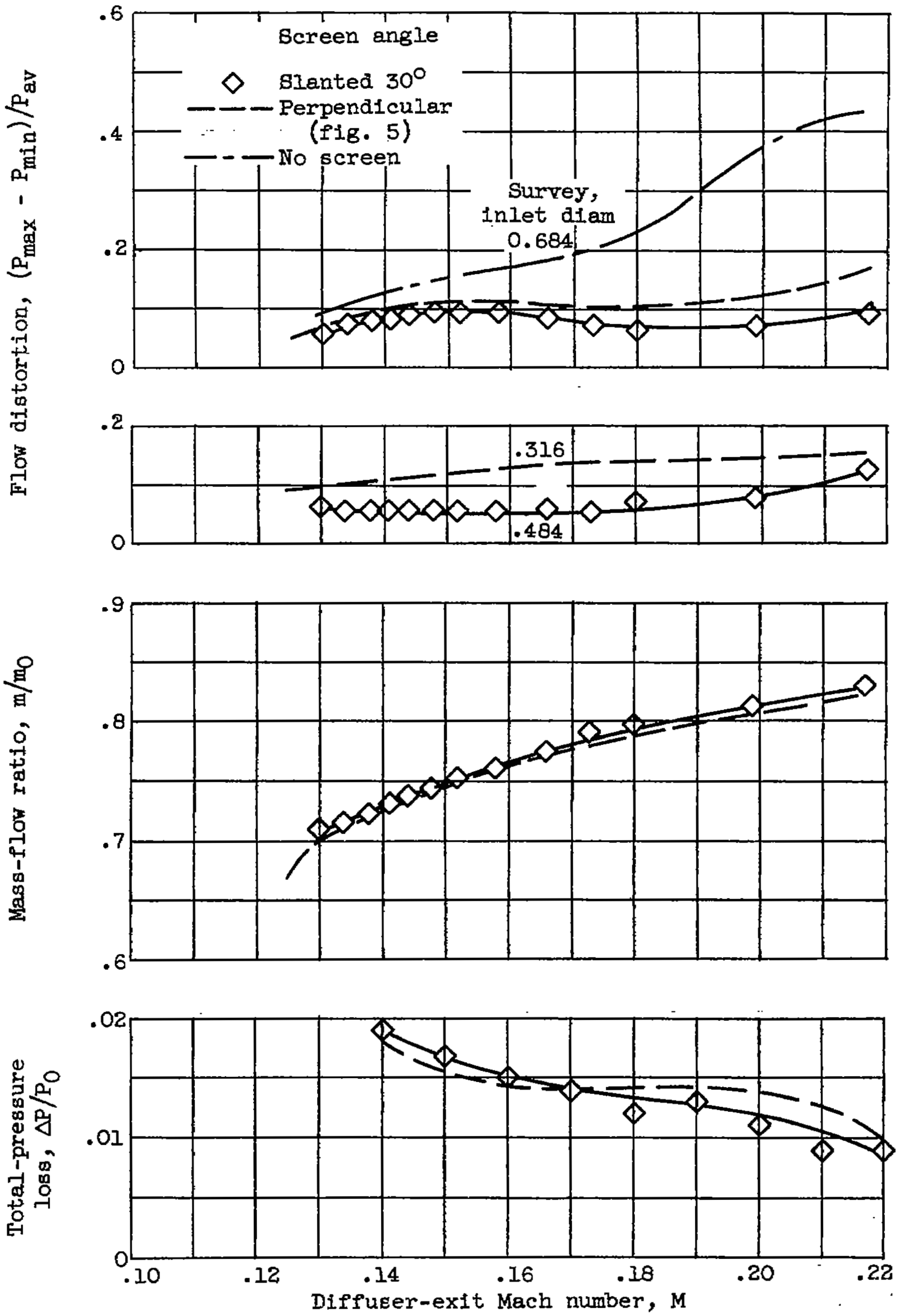
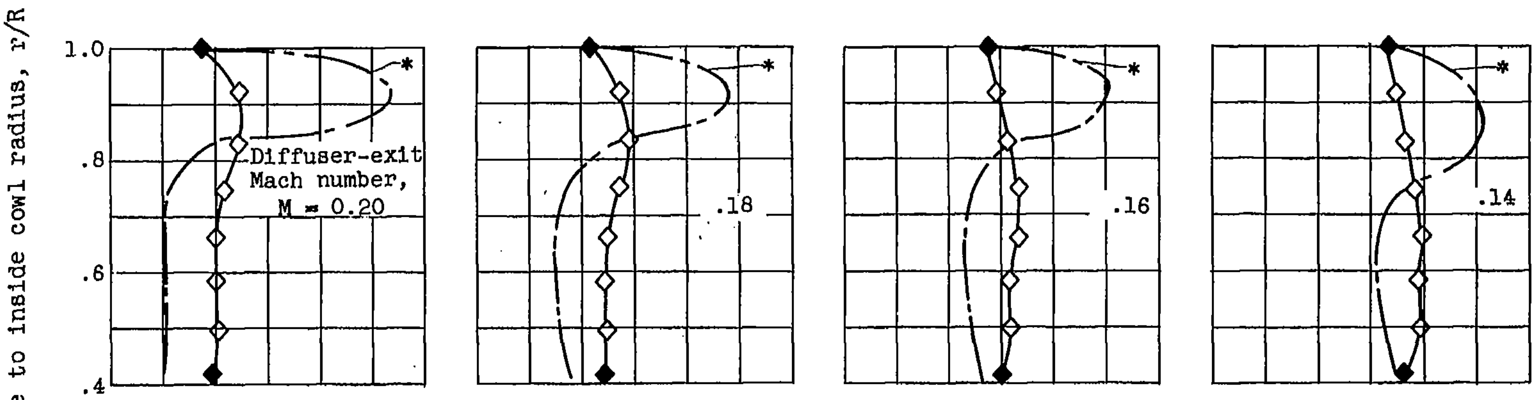
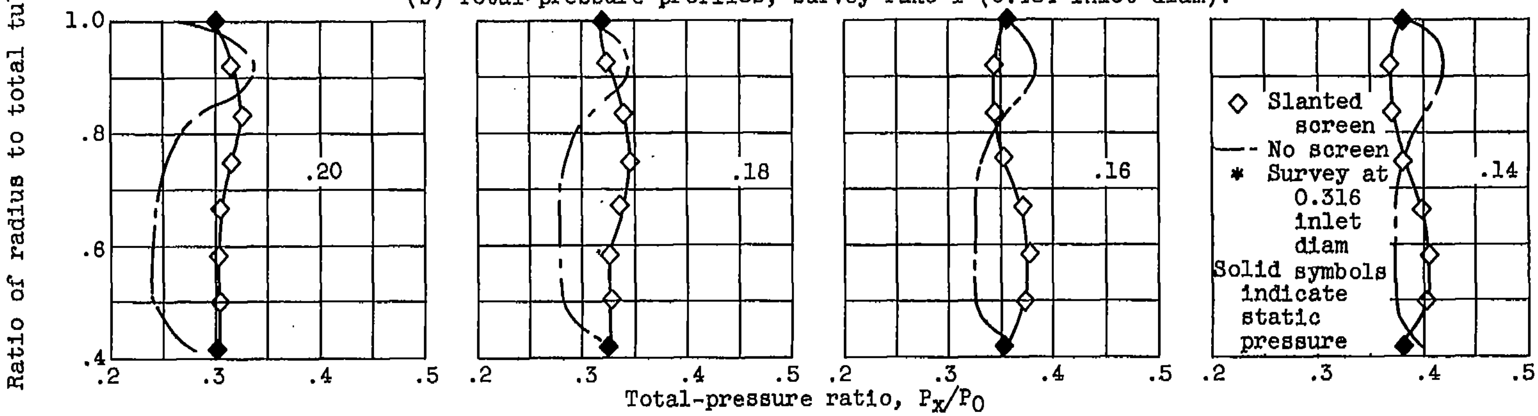


(a) Flow distortion, mass-flow ratio, and total-pressure loss.

Figure 6. - Effect of slanting screen 30° to flow direction. Screen solidity, 0.41.

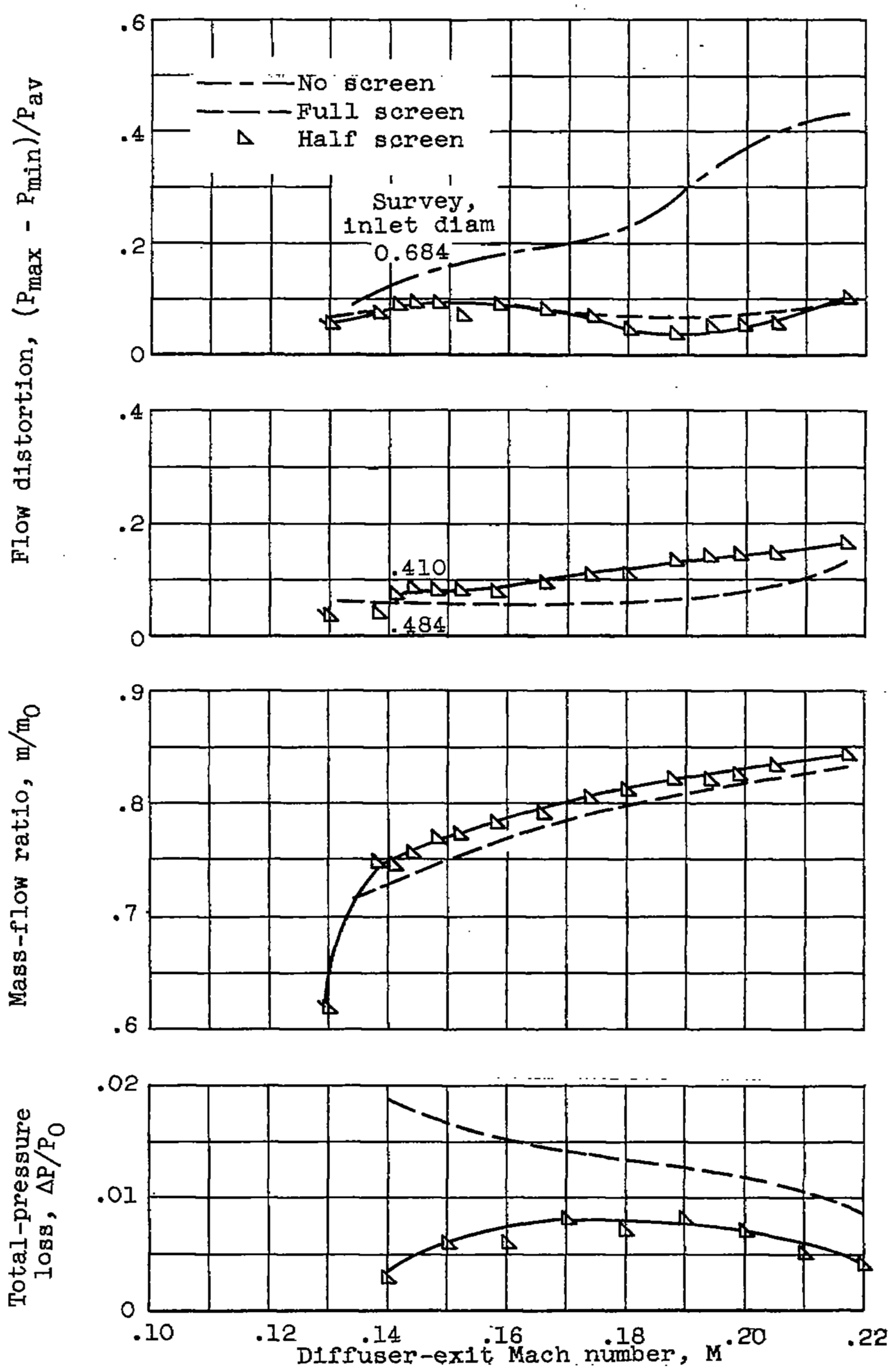


(b) Total-pressure profiles, survey rake 1 (0.484 inlet diam).



(c) Total-pressure profiles, survey rake 2 (0.684 inlet diam).

Figure 6. - Concluded. Effect of slanting screen 30° to flow direction. Screen solidity, 0.41.



(a) Flow distortion, mass-flow ratio, and total-pressure loss.

Figure 7. - Effect of half and full screens slanted 30° to flow direction. Screen solidity, 0.41.

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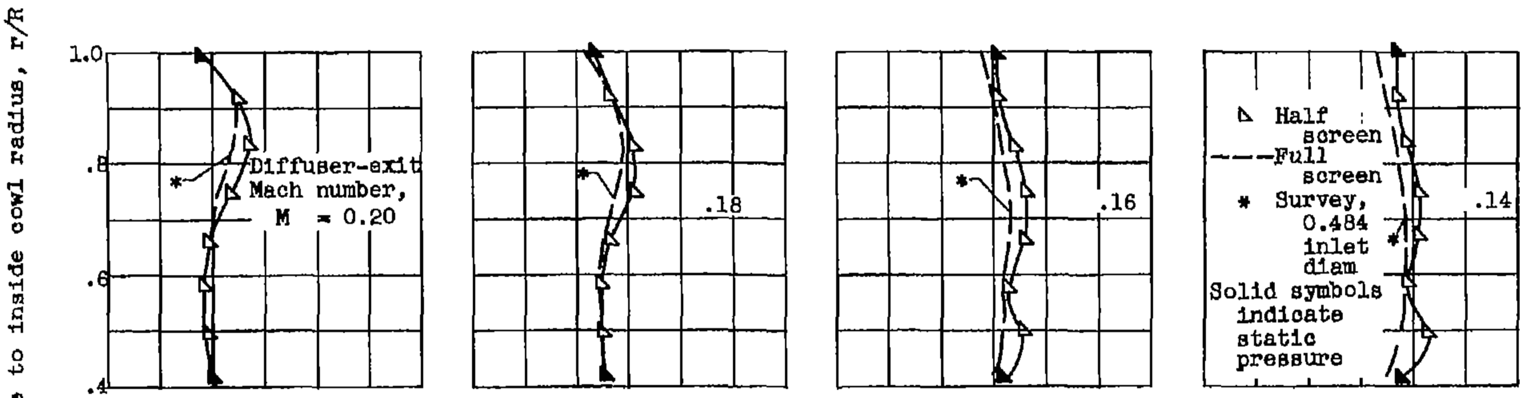
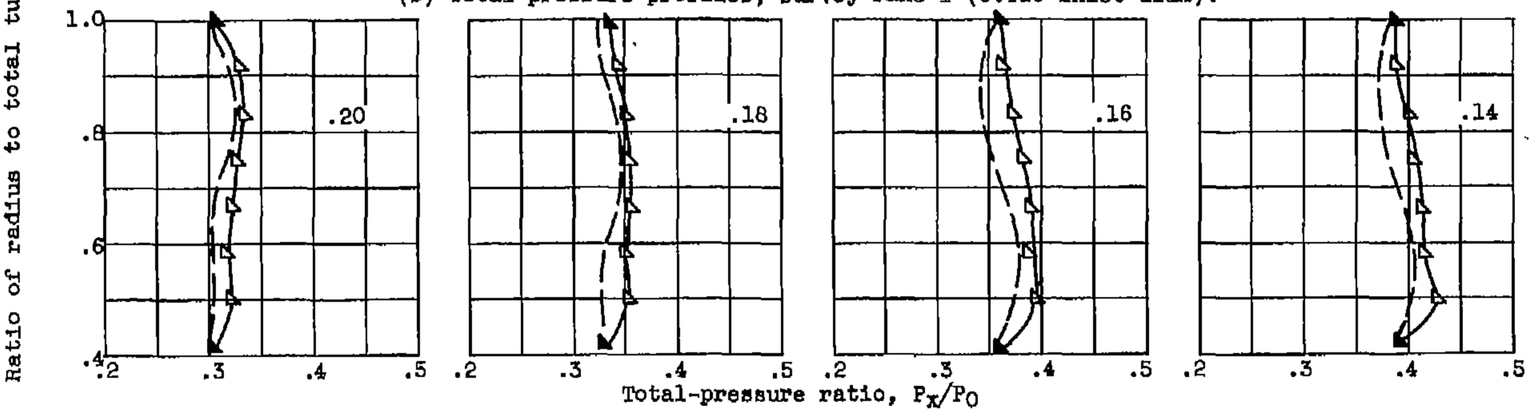


(b) Total-pressure profiles, survey rake 1 (0.410 inlet diam).



(c) Total-pressure profiles, survey rake 2 (0.684 inlet diam).

Figure 7. - Concluded. Effect of half and full screens slanted 30° to flow direction. Screen solidity, 0.41.

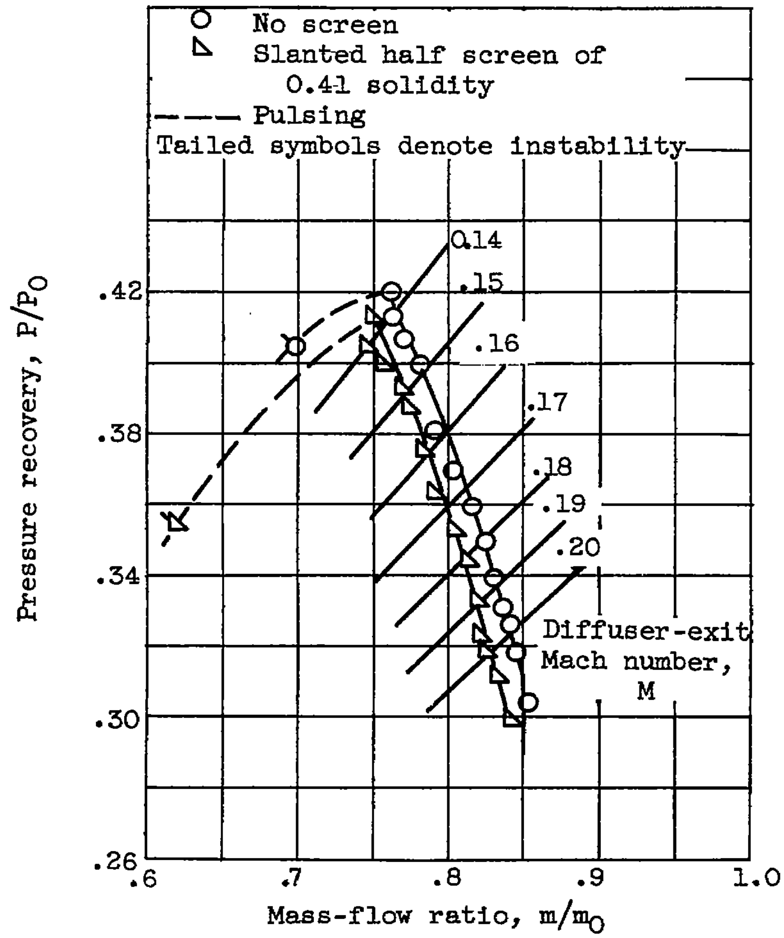


Figure 8. - Diffuser characteristics for no-screen and 0.41-solidity, slanted half-screen configurations.

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